FOOTING RESPONSE UNDER PASSIVE ISOLATION

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SUMMARY

The paper describes the experimental study conducted to find the reduction of vertical dynamic stress intensities and decelerations of the footing itself by the "Passive Isolation techniques". Results of foundation response to soil-transmitted loads, with the placement of compressible materials beneath the footing at a depth of one radius, are reported and compared with those obtained without the compressible materials.

GENERAL

Apparatus and Test Procedures: The apparatus consisted of a steel pressure vessel three feet (0.91m) diameter by three feet (0.91m) deep with both ends open, and a movable steel plate positioned at the bottom inside the vessel. The vertical movement of the plate was guided vertically by three hydro-line cylinders. A 24 in. (0.61m) thick layer of dry uniformly graded Ottawa sand was used as a soil media inside the vessel. The uniform placement of the sand in the vessel was obtained by a slow rain of sand termed pluvial compaction (Kolbuszewski and Jones, 1961). Use of this "raining technique" with a free fall distance of 12 in. (30.5cm) produced medium densities of the order of 104.5 ± 1% (1.674gm/cc.) As the vessel was being filled with sand to the desired height, a compressible material (sponge or rubber) was buried at a depth of one footing radius below the proposed footing level.. Embedded stress gage was positioned in the sand at mid-depth between the expected footing level (surface of sand layer) and the compressible material buried at one footing radius. After the vessel was filled with sand to the desired height and with the compressible material and stress gages oriented at desired locations, the surface was levelled and the footing was placed on the surface at the center. The footing selected was of six inch (15.24cm.) diameter and with a contact pressure of 0.55psi (3.8 KN/m). The footing size was selected to obtain semi-infinite conditions of sand layer beneath the footing. The diamter ratio of the vessel to the footing, in these experiments, was six.

Loading Apparatus for Static Tests: A series of static load-displacement tests were conducted for the six-inch (15.24cm.) diameter surface footing with and without a compressible material buried in the soil. The load was applied to the footing slowly, at a constant penetration rate, through a gear box arrangement. The footing pressure was measured by means of a proving ring, and the penetration was measured by a deformation dial gage.

Loading Apparatus for Dynamic Tests: Dynamic tests were conducted in the same vessel under the same conditions as the static tests. Ground motions, induced mechanically using a loading apparatus specially designed for this

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purpose, were transmitted to the footing through the underlying layer of sand mass by moving the bottom steel plate. Details of the loading apparatus have been described by Varadhi and Saxena (1980).

Instrumentation: Stress-time measurements were recorded by using the piezo-resistive gages developed at the Illinois Institute of Technology Research Institute (Selig and Tobin, 1966). These stress gages were calibrated both under hydrostatic conditions and in confined specimens of sand. Acceleration-time response of the bottom movable steel plate and the footing were recorded by means of accelerometers (High Resonance Frequency, Shock Accelerometer Model 2225, Endeveo Dynamic Instrument Division) mounted as shown in Fig. 1. Output form the stress gages and accelerometers were stored on a magnetic tape. For this purpose a 14-channel magnetic tape recorder (Magnetic Tape Recorder, Model 5600B, Honeywell) and a visicorder (Model 1508B, Honeywell) were used. The visicorder was used to print the data stored on the magnetic tape.

FOOTING RESPONSE

Transient loads were transmitted to the bottom of the footing through the underlying soil mass. The acceleration-time response of the bottom movable steel plate (A_B) and the footing (A_T) were recorded by means of accelerometers mounted as shown in Fig. 1. The input, acceleration-time response, for all the tests in this experimental program was maintained almost the same. The actual values of these acceleration-time responses were not used in any analyses herein, but used as a reference. The footing acceleration-time response (A_T) consisted of two peaks corresponding to the trace. The average value of maximum peak deceleration amplitude for a 6 in. (15.24cm) diameter footing (σ_C=0.55 psi or 3.80 kN/m^2) measured from zero line is 4.87g. This peak attenuated in about 12.5 msec. to 50 msec. The pattern of the latter portion of the footing response trace is almost similar to the response traces of the actual structures under explosion-induced ground motions (Medearis, 1975). They differ only in their amplitudes and time.

ANALYSIS OF RESULTS

In the past, various isolation techniques have been used for the earthquake problem to reduce the effect of transient loadings on the structure. A passive isolation technique was used in this investigation. For this purpose four sponge materials and a rubber material having different compressible characteristics were used. These compressible materials were of the same size as the footing (6 in. or 15.24 cm diameter circular) and their thicknesses varied from 0.25 in. (6mm.) to 0.5 in. (12 mm). Static compression tests were conducted on these materials, and stress versus deformation relationships were obtained. Using these relationships, subgrade modulus (K_C) of each compressible material at static contact stress (σ_C = 0.55 psi or 3.80 kN/m^2) level was computed. For example:

K_C = static contact stress/deformation, corresponding to the static contact stress , (psi/in. or kN/m^3).

Acceleration-time response fo the footing was recorded with a footing on the surface, but without any compressible material buried in the soil.

A series of dynamic tests were conducted with a combressible material buried beneath the footing at a depth of one radius. Percentage reduction in deceleration (R_a) of the footing was computed for each use. These R_a values were plotted against the K_c values and a relationship was obtained. On an R_a versus log K_c plot, a straight line relationship is obtained, represented by the equation $R_a = A_1 - A_2 \log K_c$, where A_1 and A_2 are constants. Percent reduction of the peak veritcal stress (R_s) at $R/r = 0$, $z/r = 0.5$ corresponding to each compressible material were computed and plotted against the K_c values. On a log scale a straight line relationship represented by the equation $R_s = 89.3 - 30.7 \log K_c$ was obtained. This equation can also be expressed in a generalized form as $R_s = A_3 - A_4 \log K_c$, where A_3 and A_4 are constants. The relationship as derived above may prove to be useful in the design of earthquake resistant structures.

The data from static load-displacement tests (with and without a compressible material buried in the soil) indicated that a linear relationship can be generated between the percentage reduction in the factor of safety (based on allowable settlement) of a surface footing (R_F) and percentage reduction in deceleration of the footing (R_a).

The above conclusions were drawn on small scale model tests. A comparison of small scale model test results with large prototype structures may prove helpful in developing some similitude criterion and may also provide better understanding of the influence of the vertical component of earthquake induced forces. It must be recognized that information from large size structures in a meaningul form may not be available now and obtaining the information may involve considerable time. Furthermore, it may not be possible to establish one-to-one scale factors between the small models and prototype structures, but relationships similar to those presented in this investigation can be developed and established.

ACKNOWLEDGEMENTS

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APPENDIX I. - REFERENCES

1. Kolbuszewski, J., and Jones, R.H., (1961), "The Preparation of Sand Samples for Laboratroy Testing," Proceedings, Midland Soil Mechanics and Foundations Engineering Society, Vol. 4, 1961, p. 107.

2. Medearis, K.G., (1975), "A Comparative Study of Structural Response to Explosion-Induced Ground Motions," A Report Prepared for the ASCE Research Council on Performance of Structures, ASCE Project 210.02/17-2.72-3, American Society of Civil Engineers, New York, 1975, pp. 1-138.

3. Selig, E.T., and Tobin, H., (1966) "Piezoresistive Soil Stress Gages," Air Forece Weapons Laboratory Report No. AFWL-TR-66-51, IIT Research Institute, May, 1966.

4. Varadhi, S. and Saxena S.K., (1980), "Foundation Response to Soil Transmitted Loads Part I - Vertical Stress Distribution Studies" - Submitted to

the Geotechnical Journal ASCE.

4. Varadhi, S.and Saxena, S.K., (1980), "Foundation Response to Soil Transmitted Loads Part II - "The Footing Isolation Studies," - Submitted to the Geotechnical Journal ASCE.

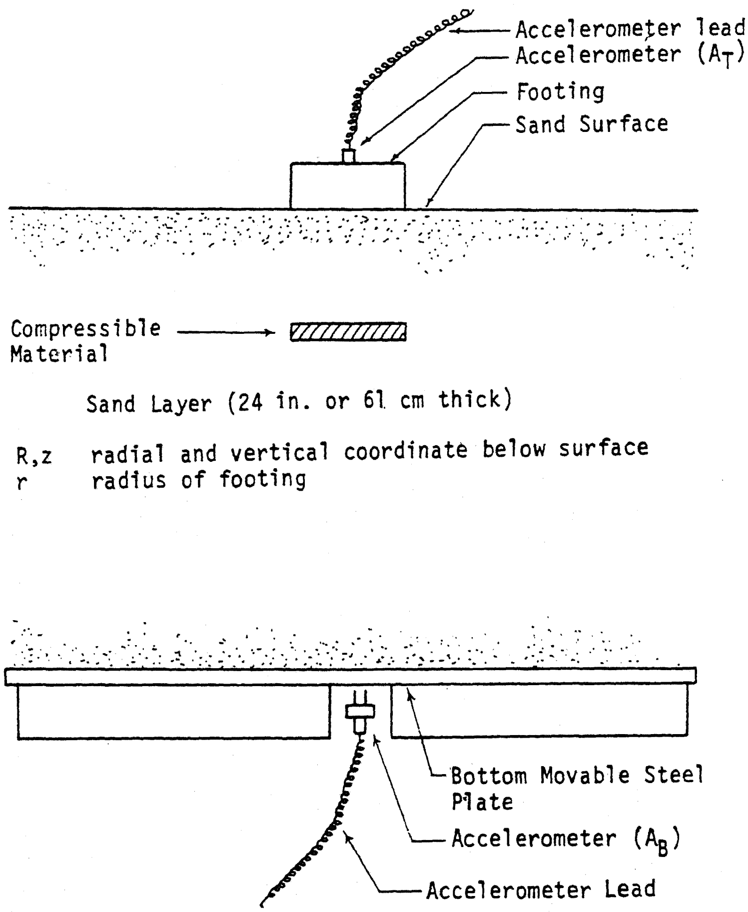

Figure 1. Schematic Diagram of Footing Apparatus